IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application no.	:	09/992,941	Confirmation No.9187
Applicant	:	Ira Jeffrey Bush	
Title	:	ALL FIBER AUTOCORRELATOR	
Filed	:	November 5, 2001	
Art Unit	:	2877	
Examiner	:	SAMUEL A. TURNER	

Docket no.	:	OPTI-0008
Customer no.	:	24507
Confirmation No.	:	9187

Date: April 16, 2004

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Declaration Under 37 CFR §1.132

I, Ira Jeffrey Bush, of Los Angeles, California, hereby declare that:

1. My education and experience in the field of fiber optic interferometric measurement techniques and instrumentation is disclosed in the attached curricula vitae ("Biographical Sketch") which is hereby incorporated into this declaration by reference.
2. The placement of Faraday rotator mirrors at the end of a single mode fiber in an all-fiber Michelson interferometer having coherence light source is known in the field to reduce or effectively eliminate polarization fading. The polarization-rotating properties of the rotating medium of the Faraday rotator are typically tailored to the wavelength of the selected coherent light in order to maximize the restorative effects to the light of the return path. Accordingly, and prior to the present invention, skilled practitioners in the field expected no practical benefit from the application of a Faraday rotator mirror to a single mode fiber in an all-fiber Michelson interferometer having a broadband light source and, as it logically follows, where the single mode fiber providing both the outbound and return path is wound about a high efficiency

modulated fiber stretcher that produces a beam having a very large path length modulation amplitude (e.g., thousands to tens of thousands of radians causing hundreds of radians of birefringence modulation) and relatively rapid modulation period, even less benefit in reducing polarization fading, if any, would have been expected from the application of a Faraday rotator mirrors in such an interferometer as that of the present application.

3. The unexpected and unobvious results were that: (a) the single mode fiber autocorrelator of the present invention having piezoelectric fiber stretchers and using Faraday rotator mirrors (FRMs) and a broadband light source, produce high visibility and near transform-limited resolution; (b) the single mode fiber autocorrelator of the present invention having piezoelectric fiber stretchers and using Faraday rotator mirrors and a broadband light source and a coherent light source within 25% of the design wavelength of the Faraday rotator mirror using the same path, produce near transform-limited resolution as well as an accurate displacement measurement index (from zero crossings from the coherent source).
4. The resulting design of the all-fiber autocorrelator stemmed from my attempt at finding a practical cost effective solution to using Michelson-based interferometers in the clinical environment. Many clinical applications for Optical Coherence Domain Reflectometry (OCDR) or Optical Coherence Tomography (OCT) require the use of disposable probes and there is an enormous cost advantage to be able to use single mode (and associated low cost single mode connectors) rather than high-cost Polarization Maintaining (PM) fiber (and associated high-cost PM connectors). Numerous Michelson approaches implementing polarization correction techniques were considered, and abandoned due to either complexity or technical inadequacy. Contemporaneously, I was leading some other unrelated research using coherent systems (with narrow line lasers) which involved minimizing the birefringence modulation of a high efficiency modulator (e.g., a fiber-wrapped, piezoelectric element) and was able to come to a solution which involved combining the modulator with a circulator and a Faraday rotator mirror and was able to reduce birefringence modulation from a level of about 100 radians to less than 0.1 radian. I then considered this approach as a possible technique for the OCT / OCDR technologies

which implement broadband sources (still within Michelson format) and initially rejected it as it was not obvious that FRMs would be effective with a broadband optical source and use of the FRM could only be applied in the reference leg. Some short time later, while reviewing other prior art (US Patent 5,659,392), the idea of the autocorrelator instead of the Michelson interferometer could be used for OCDR and OCT applications, and here, the FRMs could be used in both legs of the interferometer, and the interferometer could be manufactured with all single mode fiber allowing for a single mode probe, which would then accomplish my previously mentioned objective. I discussed this with my peers at Optiphase, particularly those skilled in the art, and their conclusion was that the FRMs would not be effective enough to reduce birefringence modulation enough to obtain anywhere near transform-limited operation. Given the complex and time consuming analysis required to prove or disprove the opinions without experimentation, I decided to build an all-fiber autocorrelator and empirically determine the performance. This was done and much to my and my co-workers surprise the all-fiber autocorrelator was found to offer almost near ideal performance. This approach, when considered for OCDR and OCT applications can most definitely be considered as unobvious. As further evidence to the unobviousness, recently Optiphase has placed substantial literature into the "open" to attract customers to this effective and low-cost and otherwise unknown and unpracticed approach. The dominant response I have received, especially by those skilled in the art, is disbelief of the performance or outright rejection of the approach as a solution as not being operable or otherwise effective. Optiphase has managed to convert some opinions, but typically only after significant education of those otherwise skilled in the art and demonstration to these persons of a prototype embodiment of the present invention.

5. A recent real market example of an industry need for a cost effective solution to the PM Michelson interferometer such as the all-fiber autocorrelator is cited. Imalux Corporation in Cleveland OH is a company formed to use OCT for detection of early stage cancer in a number of clinical fields including gynecology, urology, gastroenterology, and dermatology. They have licensed the Gelikonov et al patents (5835642, 5867268, and 6608684) and had developed all-fiber prototype OCT

prototype OCT instruments implementing PM Michelson interferometers implementing the design concepts outlined in the above referenced patents. In January 2003, they became aware of the Optiphase all-fiber autocorrelator and its associated configuration and cost benefits. In July 2003, they funded Optiphase to demonstrate compatibility of the all fiber autocorrelator to their probe assemblies based US patent no. 6,608,684 to Gelikonov et al. At that time Imalux also presented the all fiber autocorrelator design concept to their consulting research group comprised of Valentin Gelikonov, Grigory Gelikonov and others for review. The response of this group of skilled practitioners was that the all-fiber autocorrelator approach was one which was overlooked (by them) ostensibly due to unobviousness and was worthy of evaluation. Such evaluations were made with the net result of Imalux changing their OCT design to implement the all-fiber autocorrelator. In March 2004, Optiphase entered into a manufacturing arrangement to produce all-fiber autocorrelators for Imalux to support their clinical trials and early sales of OCT medical diagnostic instruments.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 USC §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Executed this sixteenth day of April 2004.

Ira Jeffrey Bush

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE
Ira Jeffrey Bush	President, Optiphase, Inc.

EDUCATION /TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR(S)	FIELD OF STUDY
University of Central Florida	B.S.E.	1978	Electrical Engineering
University of Central Florida	M.S.E.	1981	Electrical Engineering

RESEARCH AND/OR PROFESSIONAL EXPERIENCE:

1979-1982 **Engineer, Naval Research Laboratory,** Supported the Navy's FOSS (Fiber Optic Sensing System) program. Designed and developed a unique fiber interferometric synchronous detection technique used in the Navy's first prototype underwater fiber acoustic sensor.

1982-1988 **R&D Manager, Litton Systems, Inc.** (now Northrop Grumman Guidance and Control) Managed IR&D groups involved in developing fiber acoustic sensing arrays and fiber optic gyros. Key developments include: 1) Worlds first Time Division Multiplexed (TDM) fiber optic sensing array with all digital interferometric interrogation / demodulation ; 2) closed loop fiber optic gyro; 3) Munitions grade miniaturized fiber optic gyro.

1988-1989 **VP, New Product Development, Dylor Corp**, Directed new product development in the interferometric fiber system and sensor areas. Focus on integrated optic external modulation, miniature remote fiber acoustic probe utilizing coherence multiplexing (a precursor technology to Optical Coherence Reflectometry), and various fiber based interferometric vibration and acoustic sensors.

1989-1990 **Consultant** Fiber Optic Sensor R&D to numerous organizations.

- Bendix Oceanics: (now L3 Ocean systems) Hydroacoustic fiber optic sensor arrays, fiber telemetry.
- Advanced Cardiovascular Systems: (now Eli Lily). Development of fiber optic acoustic probe to be used in conjunction with Laser Angioplasty used for laser pulse and ablation diagnostics.
- Raychem (Raynet subsidiary): Developed integrated optic external modulated performance models for fiber optic CATV distribution.

1990-present **Founder and President, Optiphase, Inc.** Overall responsibility for this small business, including technical direction of the majority of projects and functions of the Company. Key research projects are listed.

- NASA Jet Propulsion Laboratory: Development of space qualified elements for backup fiber optic gyro for Cassini mission. Developed fiber delay coils for satellite data telemetry system.
- Good Samaritan Hospital, Los Angeles: Probe development and ablation studies for laser angioplasty.
- Naval Research Laboratory: Interferometric demodulation technology for fiber acoustic sensing
- NASA Goddard Space Center: Fiber Gyro Development for Satellite Navigation
- Office of Naval Research: Multi-Channel Interferometric Demodulation System
- University of San Francisco, Lawrence Livermore Labs, NIST, Univ. of Connnecticut:: Developed Polarization Sensitive, OCR system (initial design) embodying all-fiber design, used for dental and biological tissue research leading to OCT laboratory work and publications by those institutions.
- IntraLuminal Therapeutics, Inc: Developed and Commercialized all fiber Optical Coherence Domain Reflectometer (OCDR) assembly, which is now used in their Safe-Cross™ product . Have manufactured over 150 units for clinical applications.
- Eastman Kodak: Developed dual wavelength, all fiber autocorrelator OCR system used as production quality tools for film manufacturing, and digital camera CCD frame profilometry
- Bioluminate, Inc. Developed all fiber autocorrelator (OCDR system) used in their "Smart Probe" system for minimally invasive breast biopsy / lesion diagnostics measurements.
- FDA, Johns Hopkins University, University of Washington, Phizer, Merck: Manufactured autocorrelator OCR systems and supported their associated research (mostly biomedical related)
- Imalux Corporation: Developed all fiber autocorrelator OCR assembly as low cost replacement for PM Michelson OCR system. Have entered contract arrangement to manufacture 100 OCR units

Selected Publications:

I. J. Bush and Allen Cekorich **"Commercialization of Interferometric Interrogation Techniques for Fiber Sensing Applications,"** *15th Optical Fiber Sensors Conference Technical Digest,* IEEE Catalog Number 02EX533 (6-10 May 2002, pp 371-274).

II. J. Bush *et al.* **"All-Fiber Optic Coherence Domain Interferometric Techniques,"** *Proc. SPIE, Fiber Optic Sensor Technology II,* Vol. 4204, (6-8 November 2000, pp 71-80).

III. J. Bush *et al.* **"Buried fiber intrusion detection sensor with minimal false alarm rates,"** *Proc. SPIE, Fourth Pacific Northwest Fiber Optic Sensor Workshop*, Vol. 3489, (6-7 May 1998).

IV. J. Bush, A. Cekorich, **"Multi-channel interferometric Demodulator,"** *Proc. SPIE, Third Pacific Northwest Fiber Optic Sensor Workshop*, Vol. 3489, (6-7 May 1997).

V. J. Bush *et al.* **"Low-cost fiber optic interferometric sensors,"** *Proc. SPIE Second Pacific Northwest Fiber Optic Sensor Workshop*, Vol. 2872, (8-9 May 1996).

US Patents

US application 10 / 113,613 Dual Slope Fiber Optic Array Interrogator, filed April 02, 2002, **accepted by the USPTO Feb 2004** will grant May 2004.

US 2003/0086093 All Fiber Autocorrelator, Application published May 8, 2003, still pending through RCE submission

#5,903,350 Demodulator and Method Useful for Multiplexed Optical Sensors; May, 1999.

#5,095,286 Fiber Optic Receiver and Amplifier: April, 1992.

#5,094,534 Coherent Selective Fiber Optic Interferometric System: March 10, 1992.

#5,042,086 Method and Means for Transmitting Large Dynamic Analog Signals in Optical Fiber Systems.August 20, 1991

#5,012,088 Remote Fiber Interferometric Vibration Sensor with Enhanced High Frequency Sensitivity: April 30, 1991

#4,789,240 Wavelength Switched Passive Interferometric Sensor System: December 6, 1988

RECENT APPLICABLE RESEARCH SUPPORT

DOC/NIST 50-DKNB-0-90118 Principal Investigator (2000-2002), SBIR PHASE II

Optical Coherence Tomography Based Fiber Optic Sensor

The overall objective of this research was to develop a Polarization Sensitive Optical Coherence Tomography system which simultaneously provided high resolution and a rapid sweep speed. The specific aims of the work were: 1) Conduct system analysis to determine criteria to obtain shot noise performance; 2) research existing semiconductor optical source technology to determine what devices are available to provide the highest resolution at an operating wavelength of 1300nm; and 3) Fabricate a PSOCDR system based on findings from aim 1 and 2 and integrate with existing NIST materials test station so that they may obtain high resolution images of composite materials being investigated. Work was conducted successfully in that a PSOCDR system was analyzed and fabricated based on analysis results and delivered to NIST for materials research. Also this work had sufficient funding left over to manufacture an all-fiber autocorrelator which was also delivered to NIST where the capabilities of this instrument provided a scan rate in excess of 10 meters/sec.

EASTMAN KODAK (privately funded) Principal Investigator (2000-2002),

Dual Wave Autocorrelator for industrial measurements

The overall objective of this research was to develop an all-fiber white-light interferometric measurement system which was capable of replacing a measurement system (developed jointly by Hewlett Packard and Eastman Kodak) based on US patents 5596409 and 5659392. The resulting successful effort turned out to be a dual-wave autocorrelator (OCR) instrument. Five of these instruments were subsequently manufactured for Eastman Kodak and now support various manufacturing lines.

INTRALUMINAL THERAPEUTICS INC. (privately funded) Principal Investigator (2003-2004),
All Fiber Michelson OCR Design Improvements

In 1998, Optiphase developed an all-fiber Michelson Optical Coherence Domain Reflectometer (OCDR) suitable for medical instrumentation being contemplated by Intraluminal Therapeutics. This is similar to designs developed by Gelikonov et al (5,867,268). Since CY 2000, Optiphase has been manufacturing an all-fiber Michelson OCDR assembly which is used in ILT's therapeutic instruments. In late 2003 and early 2004, research was conducted to enhance the performance and reduce the manufacturing cost. A successful design was accomplished in February 2004, and is now in early stages of manufacturing.

IMALUX CORPORATION (privately funded) Principal Investigator (2003-2004),
All Fiber Autocorrelator Investigation

In early 2003, Optiphase was approached by Imalux to determine if the all-fiber autocorrelator was a suitable OCR device to be used for Imalux's OCT imaging instruments (business areas include numerous applications for imaging tissue microstructure). At the time, Imalux already had a design based on Polarization Maintaining Fiber in a Michelson configuration, (based on Gelikonov et al (5,867,268) but recognized the superior cost and ergonomics advantages of Optiphase's unique singlemode autocorrelator technology.

Interestingly, in Q3, 2003, the Optiphase autocorrelator design approach was submitted by Imalux to Gelikonov et al. (who were under contract to Imalux at the time) to review for applicability. The response from the Gelikonov team was that the Optiphase autocorrelator approach was both novel and unique, and further, Gelikonov admitted to Imalux (Paul Amazeen) that the all-fiber autocorrelator approach was unobvious. This can be corroborated by Paul G. Amazeen, Ph.D., Imalux Executive Vice President & CTO:, Tel: (216) 502-0748 **(EXT: 305)**

A research effort was funded by Imalux to investigate the ability of the Optiphase autocorrelator to be integrated to the Imalux imaging probe and obtain high resolution images. This effort has been recently deemed as successful and Imalux has committed to a production order for Optiphase autocorrelators to be used in their imaging instrumentation.

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Declaration Under 37 CFR §1.132

I, Ira Jeffrey Bush, of Los Angeles, California, hereby declare that:

1. The test support, provided by Joseph Grau ("Pepe") Davis of Optiphase, Inc., and Michael A Marcus of the Eastman Kodak Company, was done under nondisclosure agreements wherein, as employees of their respective organizations, they were contractually bound to keep in confidence the trade secret invention of Ira Jeffrey Bush and the employer of Mr. Bush, Optiphase, Incorporated.

2. The document entitled "All-Fiber Optic Coherence Domain Interferometric Techniques," published approximately March 2001 as a Conference Record of the SPIE Photonic East 2000, Boston, MA, presented November, 7, 2000, was authored by Ira Jeffrey ("Jeff") Bush and Pepe Davis, both of Optiphase, Inc., and Michael A. Marcus of the Eastman Kodak Company.

3. The contributions to the authored work by Pepe Davis and Michael A. Marcus were supportive of the test, test procedures and results and not inventive in that their roles were

both limited to prototype test support. In particular, in the above-cited document, Mr. Davis provided design, development and test support leading to the information presented in subject matter in sections 1 and 2 supported by figures 1,6, 7, 8, 9, 10 and 11, which are independent, and otherwise exclusive of, the subject application covered in sections 3.1 and 3.2, figures 13, 14, 15, and 16. Mr. Marcus provided test support contributing to section 3.2 and figure 17 of the instant invention of Jeff Bush, where all references are directed to the document of paragraph number 2 of the Declaration.

4. Messrs. Davis and Marcus are not inventors in this case and the only inventor is the Applicant, Mr. Bush. Only Mr. Bush, to the exclusion of Messrs. Davis and Marcus, contributed the novel and unobvious matter that is the matter described in the specification of the instant application and the related material matter of the above-cited document.

5. This document was a joint publication by Messrs. Davis and Marcus of the test support of Messrs. Davis and Marcus and by Mr. Bush of the overviews of some prototypical embodiments of the instant invention of Mr. Bush.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 USC §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Executed this sixteenth day of April 2004.

Ira Jeffrey Bush